How Does Electronic Discourse Support Students' Scientific Inquiry In An Internet-Enhanced Collaborative Learning Environment?

Soo-Young Lee & Nancy Butler Songer
The University of Michigan

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Introduction

The scientific community has its own ways of communicating and shares a special language among its members. Learning science means that students can communicate with each other and with other scientific community members using the socially shared discourse of science (Anderson and Palincsar, 1997; Lemke, 1990; Rosebery, Warren and Conant, 1992). New technology allows us to alter science classroom discourse by having diverse participants from beyond a classroom (with whom they are talking) and accessing professional scientific data (about what they are talking) available to students. This presentation illustrates how an Internet-enhanced atmospheric science program called *Kids as Global Scientists* provided over 10,000 students from all over the world with opportunities to communicate with scientists and other students and to study natural weather phenomena using both scientific data and first-hand experiences of participants. For example, students investigated real-time professional weather data in a certain area and made predictions for upcoming weather. Then, they compared those predictions to first-hand experience of resident participants by exchanging their predictions and results via a web-based discussion tool, the Message Board. In this scientific inquiry process (i.e. collecting and analyzing data, synthesizing and communicating ideas), the participation of scientists and appreciation of first-hand experiences encouraged students to engage in sustained and productive discussions, which were observed on the Message Board. In this paper, we will discuss communications between students and scientists that took place on the Message Board and the development of students' scientific inquiry through those communications.

As a part of symposium titled "*How can CSCL (Computer Supported Collaborative Learning) change classroom culture and patterns of interaction among participants?*", this paper attempts to answer the following three questions:

1. How does our technological innovation promote change in classroom culture?
2. How does our technological innovation alter patterns of interaction between teachers and/or students?
3. What new classroom dynamics and challenges are introduced as a result of the use of our technological innovations?

Interview excerpts, sample messages and statistical data presented in this paper were drawn from the past three years' research on the Kids as Global Scientists program (1997- 1999).

Overview of the *Kids as Global Scientists* Project and its Tools

Overview

Kids as Global Scientists (KGS) is an Internet-enhanced atmospheric science curriculum for middle school students (Songer, 1996). During the coordinated 8 week period, students, teachers and scientists from all over the world participate in the KGS program to study weather phenomena in a collaborative learning environment. KGS started with six schools in 1992 and ever since the number of participating schools has grown substantially (see table 1).

	1997	1998	1999
Schools (sites)	80	124	240
Students	4,000	6,000	10,100
Scientists	60	20	45

Table 1. Number of KGS participants during past three years

Participants came from diverse settings including home schools, science clubs, urban and rural schools. The range of participants' ages was also wide from elementary to pre-service teachers in a college-level education class. In order to facilitate productive collaboration among participants from diverse backgrounds, we grouped the similar age students in different clusters while maintaining a diverse geographical distribution in each cluster. Figure 1 shows the geographical distribution of KGS '99 participants in the US. In addition to the US participants, we also had several international participant schools in locations such as Australia, New Zealand, Canada, Finland, and Germany.

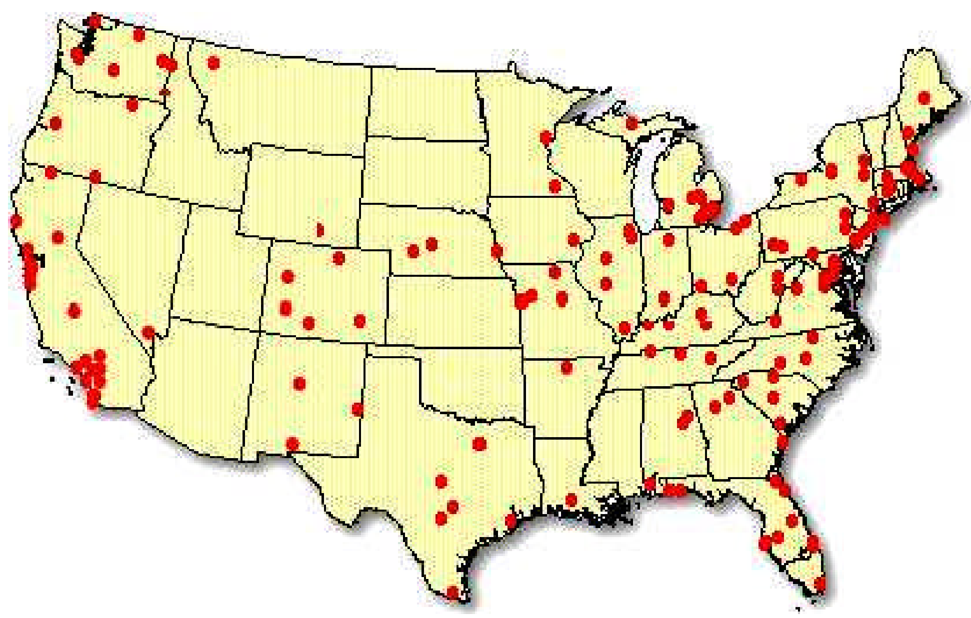

Figure 1. Geographical distribution of KGS '99 participants in the US

KGS provides the following components to help students[1] to understand weather phenomena by taking full advantage of emerging technological tools: Networked CD-ROM, Message Board and written curriculum[2].

1) **Networked CD-ROM** : The KGS CD-ROM uses a customized web-browser to retrieve professional real-time weather data and display them in age-appropriate forms (Samson, Masters, Lacy, Cole, Lee and Songer, submitted). The real-time weather data are updated hourly. In addition, the KGS CD-ROM includes archived data sets which can be used when the Internet connection is down or not available.

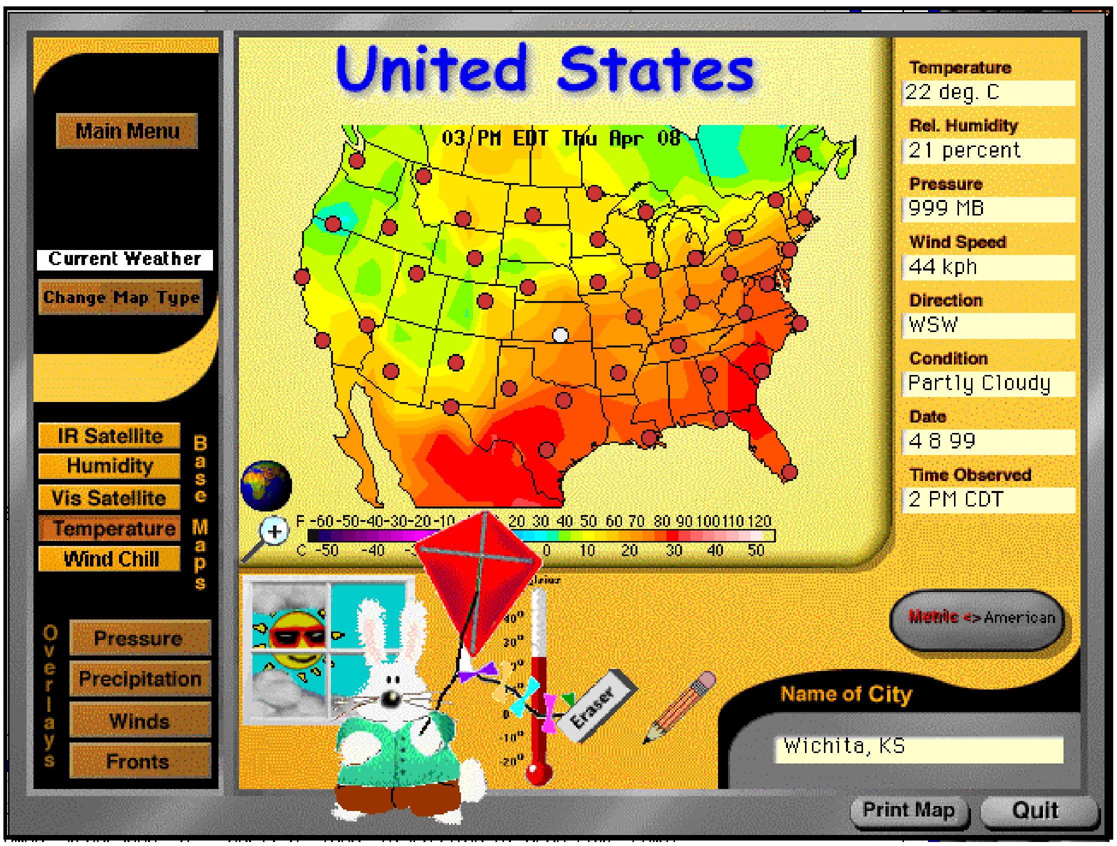

Figure 2. A screen capture from the KGS '99 CD-ROM

[1] See Songer (1999) to learn other KGS components for teachers
[2] http://www.onesky.umich.edu/kgs99

2) **Message Board** : KGS provides web-based, treaded discussion tool for communication among participants (students, teachers, and on-line scientists). Participants can post, read and respond to messages. Messages can be displayed by thread, topic, or date. The Message Board was designed to support knowledge development in a socially constructed knowledge community where interactions are mediated via electronic dialogue among peers and scientists (Songer, 1996).

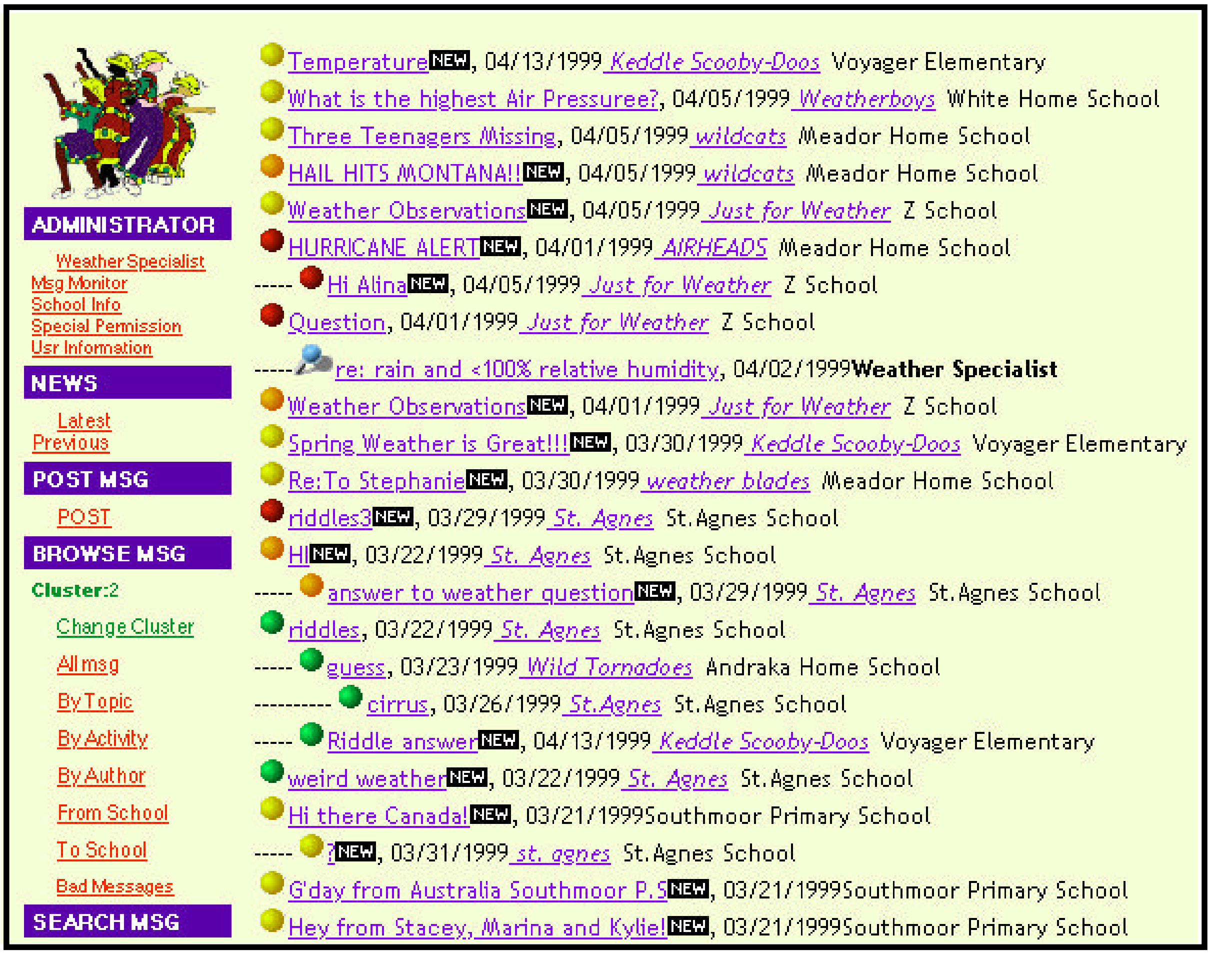

Figure 3. A screen capture from the KGS '99 Message Board

3) **Written Curriculum** : The KGS written curriculum includes inquiry-based student activities, teaching approaches, content information, classroom management tips and student worksheets. The use of KGS CD-ROM and Message Board is suggested in the written curriculum in forms of student activities. The written curriculum provides structured activities which guide teachers as they make use of the tools. However, many teachers adapt the use and integration of the tools to fit their classroom needs. Because all participants are

encouraged to do the same activity in a designated time period, they can use each other as resources and collaboration among the participants can be ensured. Table 2 shows examples of activities that use the Message Board. Participants were asked to post various types of messages during the designated time periods.

	Core Activities	Extension Activities
Phase 1 (Feb 15 -Feb 26)	▪ Introductory Messages	▪ Send questions to the Weather Specialists
Phase 2 (Mar 1 – Mar 19)	▪ Curriculum Question Communication (Winds) ▪ Real-Time Data activity: Post predictions about real time data to other schools	▪ Post a description of how to use Weather instruments ▪ Severe Weather: discussion of current storm
Phase 3 (Mar 22 – Apr 9)	▪ Data Exchange Analysis: generate question to ask to the school you compared data with ▪ Sharing your weather knowledge: Writing for the KGS '99 on-line newspaper	▪ Ask weather Specialists a questions ▪ Front activities: Send a message to a school which is affected by a front ▪ Weather Folklore

Table 2. KGS '99 Message Board activities

Study of Weather

Weather is a common natural phenomenon. Yet, it is a complex and dynamic system. Everyone experiences weather all the time, yet each of us experiences different phenomena depending on where we live. Nevertheless, both commonality and diversity exist in each of our weather experiences. At the same time, weather changes all the time. As a system, a weather condition in one location eventually affects the weather condition in another locations. Thus, weather phenomena must be understood as a dynamic system. Such characteristics of weather phenomena have been addressed in the National Science Standard along with provided reasons why meteorology should be included in science curriculum (Fisher, 1998; National Research Council, 1996; Williams, 1997).

- *Dynamic* : Weather changes from day to day and over the seasons (NRC, 1996, p. 134)
- *Quantifiable:* Weather can be described by measurable quantities, such as temperature, wind direction and speed, and precipitation (NRC, 1996, p. 134)
- *Part of system:* Global patterns of atmospheric movement influence local weather (NRC, 1996, p. 160)

- *Not always accurately predictable:* The issues of predictability and limits to predictability are of greater prominence in meteorology than in most other sciences. …. because of 1) the vastness and complexity of the earth-atmosphere system with interactions taking place on all scales from the micro-scale to global and even extraterrestrial, and 2) the instabilities of atmospheric motions (Fisher, 1998, p. 6)
- *Relevant to everyday life:* Meteorology is an area of study which is absorbing and relevant to the lives of students (Williams, 1997, p. vii)

However, weather-related information presented in a traditional science textbook is often static and out-of-date. Also, students are provided with opportunities to relate scientific weather concepts to their everyday life experiences.

KGS provides various types of information from diverse sources to support student understanding of weather phenomena. Emerging technology allows students to experience new learning opportunities in the science classroom and it leads to change in classroom culture. Table 4 summarizes the sources and the contents of information that KGS provides and how these can support understanding of the unique nature of weather phenomena described earlier.

Source and Content of Information	**Understanding the Nature of Weather Phenomena supported by KGS**
1) Visualized real-time weather data from professional weather data provider (KGS CD-ROM)	▪ *Dynamic* : Current weather information updates the changes of weather conditions ▪ *Quantifiable* : The KGS CD-ROM provides multiple representations of weather data including five basic and four overlay current weather maps, 24 hours animated weather maps, and numerical weather data for major cities (see figure 2) ▪ *Part of System* : Zoom-in and -out features allow students to explore different parts of the world.
2) Personalized scientific explanations by content specialists (Message Board)	▪ *Not always accurately predictable* : On-line scientists help students understand some weather phenomena that can not be explained by textbook examples.
3) Personal, first-hand experiences from Geographically - distributed participants (Message Board)	▪ *Part of system* : Students can talk to participants in different locations, share their experiences, make weather forecast based on their locations, and the movement of weather systems ▪ *Relevant to everyday life* : Students can relate scientific information to their personal life.

Table 4. Understanding of weather in the KGS Classroom

Question 1: How does our technological innovation promote change in classroom culture?

In this paper, I will discuss how the KGS program provides new opportunities for learning weather in K-12 science classrooms. In particular, I will focus on how electronic discourse on the Message Board can support students' scientific inquiry while they are studying weather phenomena. Examples of message exchanges in this paper were selected from the messages posted on the KGS '97, '98 and '99 Message Board.

1. Student connect personal experiences with science learning (Visualized real-time weather data)

> *I think what helped for them was being able to go into the lab and see the weather pictures from today and look and see, 'hey look it is the cloud cover and look it is cloudy outside and it is raining'. And being able to take a look at the map that was on the computer screen and look out the window and make the connection. … Whereas previous times you are dealing with, 'OK this is yesterday's weather map and it doesn't have the cloud cover on it, it just shows symbols for rain or snow or something like that …. so to make the connections between this two dimensional map of what's going on and not being able to see the 3D actual weather outside was difficult for the students, but with the KGS they were able to start making connections between the maps and the actual weather outside. (A KGS '98 teacher).*

The KGS CD-ROM provides real-time weather data updated hourly. Thus, what students are seeing on the CD-ROM represents the weather condition just outside of their classroom window. Students can experience what 20 °F with a wind speed of 10mph feet like. The following message exchanges illustrate how both scientific information and students' personal experience can be important sources of information for students to pursue their inquiry.

The Five Fog Horns, 2/25/97
We have read your weather data and we were wonder how come your wind speed did a dramatic change and have you ever witnessed a tornado or a cyclone?

> *The Whirlwinds, 2/27/97*
> Yesterday, at 2/27/97, the winds were at record highs. Those records were 70 to 100 mph. 70 mph being the slowest in the afternoon. When it started getting up to 80-90 mph it started lifting cars to other lanes without them being on the ground. It happened to us. We were flying and it was scary. Once it reached 90-100, it picked up a tractor trailer and flipped it on its side. Luckily the man inside was not hurt. These were wind gusts, but not a tornado. The tops of our highest buildings started to have their windows blown out. I heard about one person where a tree fell on their house because of the wind. It was caused by the same thing that causes tornadoes cold air coming into an area of warm air (unusually warm air for Feb. it was in the 50's), but we didn't actually have a tornado. Someone said that it is suppose to be the same way on Saturday, but not as bad.

Sample Message Exchange 1 : Connect personal experience with science learning

As a response to the first message, the second message talked about how fast the winds blew and described what happened because of the high winds in their area.

2. Students can make science learning more authentic(Personalized scientific explanations by on-line specialists)

> *A science text book is full of idealized case examples, few of which are actually observed in reality. For example, one astute young scientist noticed that a cold front passed his area but no precipitation fell. He wanted to know how that was possible. I pointed out that in science, we make generalized models to help understand something we observe, but that not all observations fit the model exactly. I'm sure he would not have learned this from a textbook or even from his teacher, who may have learned about science from similar idealized case examples (A KGS '99 Weather Specialist).*

Content specialists including professional meteorologists, graduate students and professors in the atmospheric science department around the country provide content support for students and teachers through the Message Board discussions. Real weather events often do not follow the exact rules or principles. Explanations for those exceptional conditions require substantial content knowledge. For example, science textbooks generally describe the global wind patterns. In reality, however, there are many other factors that affect wind pattern in a local area. Textbooks can not provide all possible explanations for these exceptional conditions. In the KGS program, on-line scientists provide a guidance to students as they developed understandings of their local weather phenomena more specifically than their textbook can. The following examples illustrate some questions of which answers are hard to find in the most textbooks.

- *From Freezers, 2/11/98*

…. We have a barometer in our room that we want to use but we don't know what the scale on it means. The numbers go from 960 to 1,060 and the name of the scale is BARO hPa. We've checked a couple of resources but have had no luck. Where might we find this answer?

- *Weather Specialist*, 2/4/98

We don't get much snow here in Saint Cloud. Does any body there in Saratoga Springs have any idea why Minnesota doesn't get as much snow as Upstate New York?

- *The Learning School, 3/27/98*

We have been studying winds and have some more ideas about what makes the winds so strong on Mt. Washington. … We were looking through a weather book and found out about mountain and valley wind. … Would these winds add to the high wind on top of Mount Washington?

Sample Message Exchange 2: Example of Scientists' personalized discussion

In addition, an opportunity to talk to *real scientists* is an exciting experience for many students. Sustained message exchanges between student groups and on-line scientists illustrate a motivational benefit of having on-line scientists in the KGS program (see figure 4).

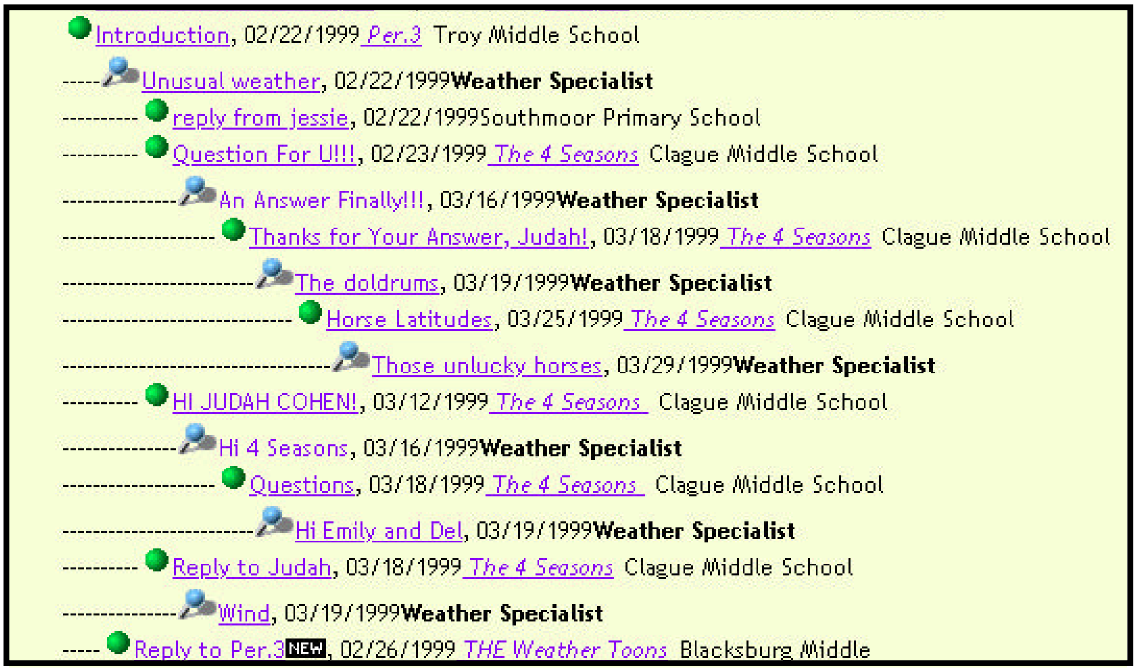

Figure 4. Message Exchanges between a student group (*The 4 seasons*) and a weather specialist

3. Students become experts/key information producers (Personal, first-hand experiences from geographically distributed participants)

> *Weather changes so quickly that I thought it would be really interesting if we would be able to monitor it real closely. … my favorite piece is that they are able to get on-line and get the Current News on the KGS CD-ROM to see what was happening, there were lots of things. .. Lots of them had great things about what was going on in the country with weather. (A teacher participated in KGS '98).*

Because the KGS participants are from diverse geographical locations, each student' personal weather experiences are unique to each other. These unique personal weather experiences are appreciated by other participants through the Message Board communication (see Sample Message Exchange 3). In addition, personal experiences can be valued when studied in conjunction with real-time data. Students like to hear what other students have to say about unusual weather events such as hurricanes and tornadoes, in addition to reading science textbooks and newspaper articles about those events (see Sample Message Exchange 4).

The Cyclones, 2/4/98
…Our climate is too hot for snow, but we get cyclones. Our climate is more suitable for swimming and surfing. Hardly anyone in our school has ever seen snow. What is your temperature range between summer and winter?

> *Three brothers, 2/23/98*
> Dear The Cyclones,
> We watched a thing on TV about "The Big Wet" talking about the end of the dry season in Australia's dessert. Do you guys have a dry season or is that just in the dessert? What are your normal temperatures like? If you want to see some pictures of snow & ice around here, go to this web site.

Sample Message Exchange 3

Windy Bob, 2/4/98
… The winters here are very snowy due to lake effect snow that we get from Lake Ontario. We want to know: have you been caught in a tornado? How fast was the wind?

> *Janet and Alice, 2/5/98*
> We have been in a Tornado but we have no idea how fast the wind was going, and we feel your pain with snow because we get a whole lot of snow cause of Lake Michigan.

Sample Message Exchange 4

Question 2. How does our technological innovation alter patterns of interaction between teachers and/or students?

> *Learning science is something students do, not something that is done to them. In learning science, students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others (NRC, 1996, p. 20).*

1. Student Initiated Discussion

The KGS classroom promotes active learners (information providers as well as consumers) rather than passive information receivers. In a traditional classroom, often a teacher dominates classroom discourse and she or he is assumed to be the authority of the classroom. This is often attributed to the Initiation (teacher) - Reply (student) - Evaluation (teacher) (I - R- E) sequence of traditional classroom discourse. A teacher asks students questions which she/he already has answers in mind. Then, students' responses are evaluated based on what the teacher expected to hear from students (Mehan, 1979, Lemke, 1990). On the other hand, discourse on the Message Board shows students' active learning process in terms of the numbers of messages that students posted. For example, out of 4,464 messages posted on the KGS '97 Message Board, students posted more than 82.8% messages. In addition, we could observe sustained dialogue among participants — between students-students and students-scientists. Figure 5 shows that 60% of the total messages (N = 4,464) were follow-up messages to other messages.

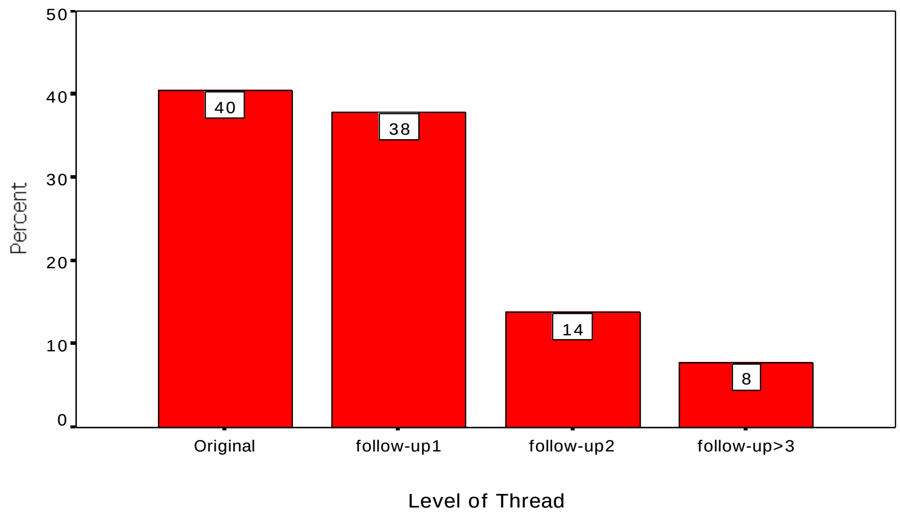

Figure 5. Percent of messages by level of thread (N= 4,464)

Figure 5 illustrates that participants were not just posting messages, rather they read other messages and communicated with each other by replying to those messages. Because the messages were being read by other participants who then replied to the messages, the senders of the messages had to be careful about their own messages, and by receiving others' comments they could rethink their original message and revise their ideas. Students also come to realize that they do not need to know everything, rather, they are learning what they did not know before by asking others who do.

Furthermore, Figure 6 shows that while 44% of the total student messages (n = 3,695) were “original messages” on a topic thread, only 24% of the total adult-participant messages (n = 769) were “original messages.” This illustrates that while students started threads of discussion and responded to other messages, the scientists and the cluster managers more often responded to students’ messages rather than initiating a new thread of conversation.

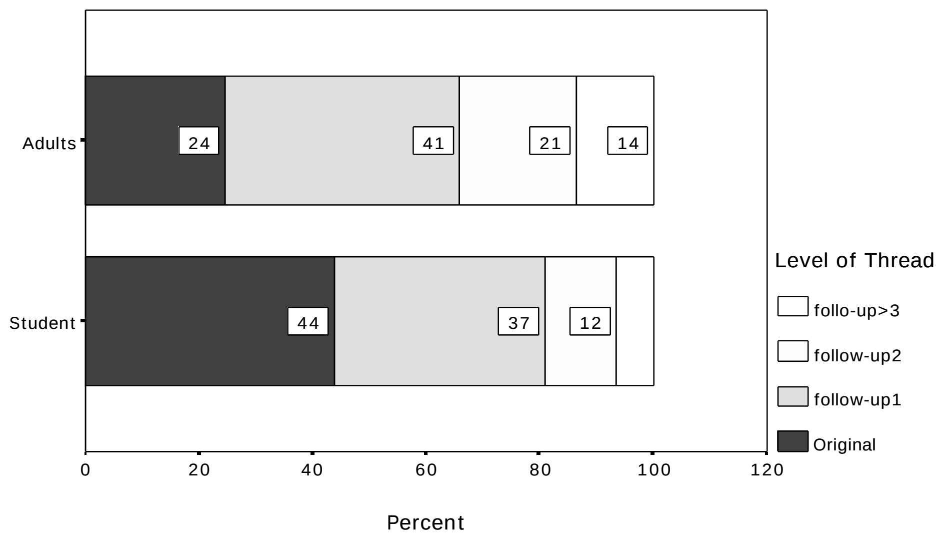

Figure 6. Percentages of thread-level messages posted by adults (n= 769) and students (n= 3,695) respectively

2. Inquiry-Based Questions

KGS students ask peers and scientists questions to get information while they are conducting collaborative investigations. Students first collect data by observing and measuring various weather phenomena at their local sites, and communicate with other participants through the Message Board or Web-based data table generated by participants themselves. Then, students process the weather data by comparing, contrasting, and classifying them. Students can use data tables and graphs to compare and contrast different sets of data. In addition, students can send messages to a school whose data they were comparing, and can discuss their comparison with the target school. This provided another medium — besides tables or graphs — to process scientific data as a part of scientific inquiry process: *communication*. Finally, students synthesize the data by generating patterns, predicting tomorrow's weather conditions, and applying their understanding to the real world situation. For example, students sent messages containing their prediction of the next day's weather for a certain school, and the corresponding school responded with the actual weather on the following day. Students also can use the professional data to check their predictions, but communication with other participants is another way to synthesize their understandings. At the same time, in order to make sense of their inquiries, students need to understand weather-related scientific concepts, relationships among those concepts, and principles and rules to explain complex weather phenomena and weather systems.

We analyzed the Message Board communication to understand the inquiry processes students used during their participation in the KGS project. Questions on the Message Board were coded based on the inquiry processes and conceptual understanding. To understand collaborative inquiry among participants through the Message Board communication, this paper will report the types of questions generated by adult participants and student participants.

Table 5 shows the percentage of questions in each category along with who generated those questions[3]. First of all, 91.1% of the total questions (N=214) were raised by students. This shows that students were active information seekers, not just passive information providers. While other studies showed that the most prevalent type of questions in a classroom is "text-based questions" which ask for simple definitions, the most frequently asked question type on the Message Board (64.0%) was the "data gathering/collecting question." These *data gathering/collecting questions* were often directed to other student participants, whereas *concept-based questions* were often directed to the Weather Specialists. Thus, it illustrates that the KGS students exploited each other's experiences and knowledge as resources by asking other participants for information they needed. It is also worthwhile to point out that the most prevalent type of questions scientists raised (47.4%) was real-time *situated questions* which are seldom found in a textbook.

Concept-based Questions	**Inquiry process based Questions**
Text-based questions: asking definition or basic information · *What causes humidity, and how are clouds formed?* · *What exactly is pressure?*	Data gathering/collecting questions: asking experience, observation, measurement, and recording data · *Tell us about the weather that you've been having lately.* · *What is the weather like in your area?* · *Does it snow where you live? What kind of precipitation do you get?*
S: 3.3% A: 0%	S: 62.1% A: 1.9%
Knowledge constructing questions: requiring explanation of scientific principles, and theories · *Does the eye of a hurricane get bigger if the hurricane gets bigger or does it get smaller? Why is the eye of a tornado more dangerous than the eye of a hurricane?* · *Why are some clouds white and some are gray?*	Data processing questions: comparing, contrasting, classifying data, and identifying anomalies · *Is it usual that there is no winds 2 weeks in a row at this time of year? or is there always no winds except for some? does the no winds have to do with where you are located on the globe?* · *Is there a difference between your day and night winds?* · *When do you get most of your snow? Early or*

[3] This analysis has been done only with the messages posted on the Cluster 3 Message Board during the KGS '97 program. Among the total of 627 messages, 214 messages contained any types of "questions".

	· *late in the winter?* · *We were wondering if 50 is common in January.*
S: 5.1% A: 1.0%	S: 5.6% A: 1.4%
Situated Questions: Real-time/ real-world related question · *I know that 3/4 of tornadoes occur in the u.s. Why is that? and why do most tornadoes occur in "Tornado Alley"?* · *How much ice does it take for it to be dangerous to fly?* · *Do the mountains make the weather and/or temperature different from where you are?* · *What is "rime"?* · *What is thundersnow?*	Data synthesizing questions: predicting, hypothesizing, generalizing, and applying to the real world · *Why you didn't have much winds even though you are in the ocean?* · *Do you get a lot of rain because there are so many clouds?* · *When do you think your next severe storm will happen again?* · *What your physical surroundings are, and how do they effect the weather in your area?*
S: 7.9% A: 4.2%	S: 7.0% A: 0.5%

(S: Student-generated question(n=195), A: Adult-generated questions(n=19))

Table 5. Category of questions on the Message Board

3. Changes in Instructional Mode

> *I did a lot of talking before[the KGS program], I still did a lot of talking with KGS but instead of whole class lecture kind of thing, it was more one on one working with the groups in the computer lab, answering their questions, so it kind of took away, took the emphasis off me and put the emphasis on the kids, in terms of acquiring the knowledge - that it wasn't 'OK Miss Lewis is going to stand up there and tell us everything that we need to know, and we just sit here and receive it and that's all you have to do'. …. It was, 'well Miss Lewis has the answers but the answers are in the computer too' and once they said OK that wasn't so hard maybe there's something else in here that's not that hard for me to find … I got to talk to small groups one on one and find out where different groups were in their understanding and it allowed students who 'oh I already get that, but I'm having problems with this', that they could spend more time with the thing that they were interested in. (A teacher participated in KGS '98)*

Another change in the patterns of interaction between a teacher and students is found in the different instructional modes a teacher employed in her classroom and in a computer lab. As the above interview excerpt illustrates, the teacher, Ms. Lewis, spent less time on teacher-directed instruction or teacher-led discussion in the computer lab. Rather she spent more time on helping each group of students to understand while monitoring individual pace of progress. Ms. Lewis again participated in KGS '99 and her whole instruction during KGS was videotaped. Table 6 shows percents of time spent on different instructional mode in the classroom and the computer lab.

	In the classroom (N = 695 minutes)	In the computer lab (N = 635 minutes)
Teacher instruction	20.9 %	0 %
Whole class discussion	**38.1 %**	1.6 %
Small group activities	7.2 %	**98.4 %**
Others (individual, video watching, etc.)	33.8 %	0 %

Table 6. Instructional modes observed in the classroom and computer lab

As mentioned in her previous year's interview, she spent most of her time in the computer lab to work with each group of students. Once students came into the computer lab, they rushed into their assigned seats and started what they were supposed to do for the day right away. Then, the teacher walked around the computer lab and checked the progress of each group. She rarely drew everybody's attention at once in the computer lab. In the computer lab students often worked at their own pace. Even though the data above come from one classroom case, the preliminary analysis suggests that using computers in a computer lab setting can change how a teacher would interact with her students. Whether such instructional changes could affect students understanding should be examined by in-depth analysis of the discourse patterns between the teacher and students in both the classroom and the computer lab.

Question 3. What new classroom dynamics and challenges are introduced as a result of the use of our technological innovations?

Our experience working in real classrooms provided opportunities to realize and understand the challenges that arise when new technology is introduced into the classroom. By presenting challenges we encountered, we would like to initiate discussions around how we should address these issues in real classrooms where new technical innovations are introduced.

1. Time: What does it take to implement new technical innovations in a real classroom?

- Planning

When new technological innovations were introduced in the classroom, one of the biggest challenges the KGS teachers encountered was time management. In many schools, teachers need to reserve a computer lab in advance. 71.4% teachers (n = 234) who responded to the pre-program survey (KGS '99) said they were going to use computers either only in a computer lab or both in the computer lab and the classroom. Thus, they had to decide when and how often they needed to be in the computer lab during the KGS program. Besides the computer lab reservation, there are many other time-related issues the teachers had to consider as they adapt technology in their classrooms. For example, a two year longitudinal study of a KGS classroom in an elementary school showed that a teacher needed significantly more time to accomplish the same numbers of activities with 8 computers in a computer lab (student-centered use of computers) than with one computer in his own classroom (teacher- centered use of computers) (Lee, H & Songer, 1998). As we described in the earlier section, student- centered use of computers — often found in a computer laboratory setting — can change teachers' instructional mode, and such change often requires more planning for teachers if they are not familiar with those situations.

- Back-up plans

In many schools, Internet connection is not always reliable. Only 6.6 % of teachers who participated in the KGS '99 program (N = 258) reported that their schools' Internet connections were "Very Reliable". For those times when the Internet is down, the KGS CD-ROM provides 4 days of archived data set to explore. These have been invaluable resources for teachers and students as a back-up plan (Samson et al., submitted). On the other hand, slowness of Internet performance presented another challenge. Sometimes the slow performance was due to the bandwidth of the Internet line in schools (57 % of KGS '99 participant schools have a Internet connection with a speed less than 96.6 K bps), and sometimes it was due to problems related to individual Internet providers or district servers. Especially this year, we also learned a great deal of what it takes to technically support over 10,000 participants. When a large number of participants were trying to access the Message Board simultaneously, students had to wait for more than 10 - 20 minutes to get a response from the server. This is a long time for students to be patient in front of computers. Simply upgrading the program-side server alone can not solve the problem, however. The solution might require systematic efforts from all levels of involvement in the system.

- Response time

Unlike face-to-face classroom discourse, asynchronous discourse on the Message Board has a time lag between initiation and response of the discussion. Students can not expect a response to their question right away. In addition to the very nature of asynchronous discussion where participants are not expected to be on-line at the same time, messages on the KGS Message Board were not instantly released to the public. In order to provide a safer discussion place, all messages were monitored for appropriateness of the message content before being released to the public board. This asynchronicity of electronic discourse can provide more time for reflection and elaboration of each message (Hsi and Hoadley, 1998). At the same time, in order to take advantage of the asynchronicity of the discussion, teachers and students should understand the process. Teachers had to consider this response lag time when they planned time for a computer lab time. For the first time participating teachers, however, it was not easy to consider these issues beforehand.

- Assessment

New technical innovations provide new learning opportunities for students and teachers as we described earlier. Since this is a new learning environment, teachers as well as researchers have not figured out yet how to assess students' learning in such new environments. For example, teachers told us they had a hard time to assess student understanding in the computer lab. One of the reasons was because many of the activities were situated in a context. Answers for a question like "*Use the KGS map to estimate which Kids as Global Scientists site in your cluster has the lowest relative humidity today?*" could vary depending cluster, day and time. Teachers can not grade the right and wrong answer for this question based on students' response on the paper at the end of day. Rather teachers might want to know how students got those answers while they are working on the computers. Assessing students' messages on the Message Board is another challenge. This assessment depends on how a teacher sets up the procedure of message posting in a class. Some teachers hardly read their students' messages while others checked all messages before their students sent them out. In addition, because each group of students often engaged in different discussion topics, reading the messages their own students composed might not be enough. Nevertheless, it takes teachers time and effort to evaluate the progress of each group as each involves a different pace and stage of development ideas.

Students should also have an opportunity to practice new assessments they are being evaluated by. For example, unless a teacher explicitly addresses the importance/awareness of scientific discourse (e.g. what is a good question to ask a weather specialist or what is a prediction?), it is difficult for students to develop an understanding of scientific discourse automatically. In a traditional classroom, students have not had many opportunities to ask inquiry-based or situated questions. Students need a chance to realize why a question like "*what is humidity*?" is not a good question for on-line scientists or other participants. Teachers should work with students to revise their questions or prediction statements in their messages over time.

2. Scaling up: How can we facilitate productive discussion among 10,000 students?

As the number of participants grows, we are encountering new challenges such as: How can we facilitate productive discussion among 10,000 students? One quick response to this challenge is to divide them into small groups, so as to operate several manageable size groups instead of dealing with one large number of participants. Literature has suggested that 10-12 schools is the optimal number to ensure collaboration (Riel, 1990). Nevertheless, this solution is not as simple as it may sound. If the number is too small, there will not be enough people to talk with. If the number is too large, then the whole discussion becomes chaotic and it is difficult to follow the discussion as a whole. Certain activities require a larger number of participants than other activities. For some activities, geographical diversity among participants would be more important than the number of participants. Providing a collaborative discourse environment where people can share their understandings has been a big challenge for us over years. As the number of messages posted per day grew, it was difficult to browse all the messages and to keep track of the discussions. In addition, we found commercial web-based discussion tools could not always meet our program needs. When we developed our own Message Board system in for KGS '99, we considered the following issues in our design to deal with a large number of messages. Our current system allows students to

- *Quickly locate the messages they posted and received from other participants:* Selective message display options such as "From my school" or "To my school"
- *Get to know whom they talk with :* List of participants' names, locations, and class photos
- *Visualize the threads of discussions :* Messages display in threads

- *Identify the senders of messages:* Different colors of icons for messages from Weather Specialists and authors in different topic groups
- *Display messages in multiple ways such as by date, author, topics :* Messages search options by date, author, activity type or topic

It is too early to talk about the actual benefits of these design decisions since the system is still in use [4]. However, preliminary classroom observation during the KGS '99 suggests that these features may help students to easily find out whether they have received any responses to their original messages out of several hundred of total messages and encourage them to exchange ideas between peers and with on-line scientists.

According to a recent document by Becker (1999), 90% of public schools in the US have Internet access in their building. This means network technology has arrived in most of the US schools. The questions we faced now are: 1) how can we take full advantage of the Internet for teachers and students in schools? 2) what are the challenges new technology introduces to a classroom? and 3) how can we overcome those challenges? In this paper, we presented how KGS can change the classroom culture and the interaction between students and teachers, and the challenges we faced over the past three years of implementing the KGS program. Our goal in this paper is to initiate a discussion, beyond the members of the educational community as well as among the community, to discuss the challenges new technology brings to the classroom and to propose possible solutions.

[4] The KGS '99 program was officially over 4/9/99, but a fair number of schools are still working on the program and using the Message Board.

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